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Konttinen et al.

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(54) **CABLES WITH CONNECTOR ASSEMBLIES, FILTER UNITS CONFIGURED TO RELEASABLY COUPLE TO THE CONNECTOR ASSEMBLIES AND RELATED METHODS**

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H01P 1/201 (2006.01)
(Continued)

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CPC ***H01R 24/40*** (2013.01); ***H01P 1/201*** (2013.01); ***H01R 9/0521*** (2013.01); ***H01R 13/622*** (2013.01); *H01R 2103/00* (2013.01)

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See application file for complete search history.

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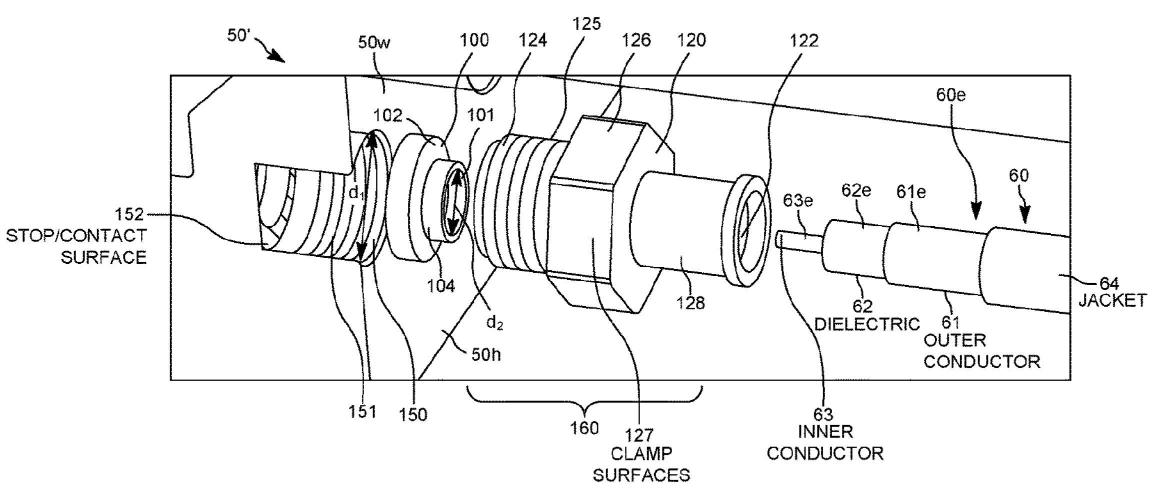
(57) **ABSTRACT**

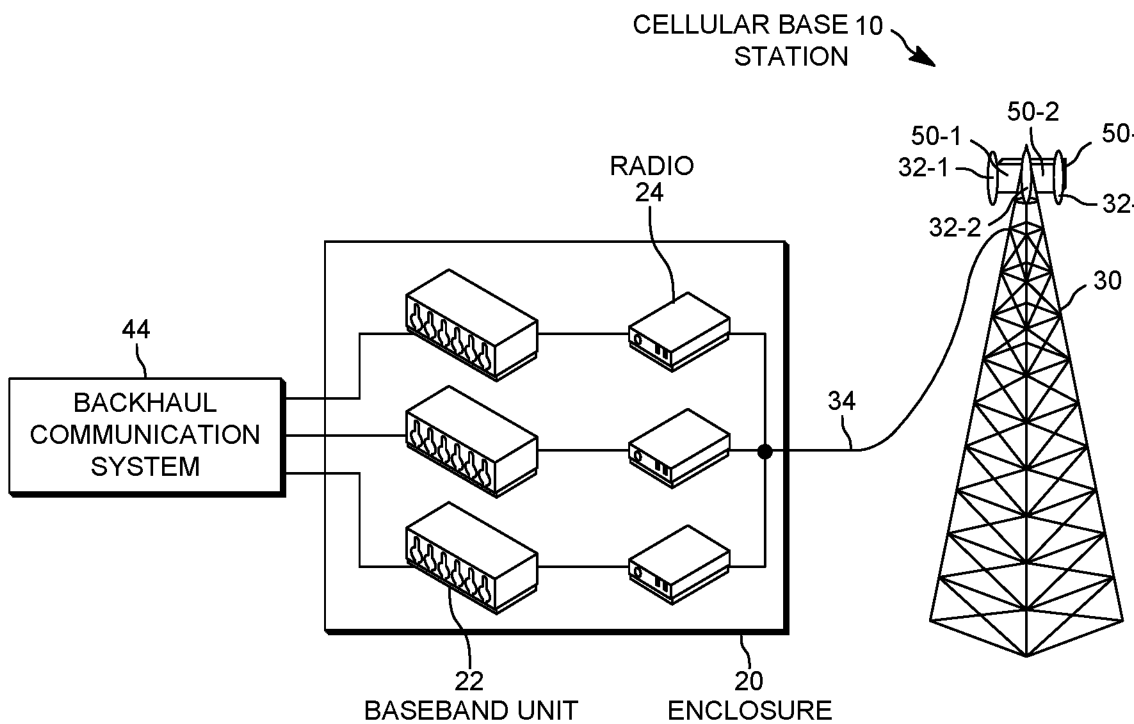
The present invention provides target devices such as filter units with at least one receiving channel with a stop surface that is electrically conductive and at least one cable with a connector assembly on a first end portion. The connector assembly includes a first member with an open channel. The first member is coupled to the end portion of the outer conductor with the free end of the inner conductor and the end portion of the dielectric extending through the open
(Continued)



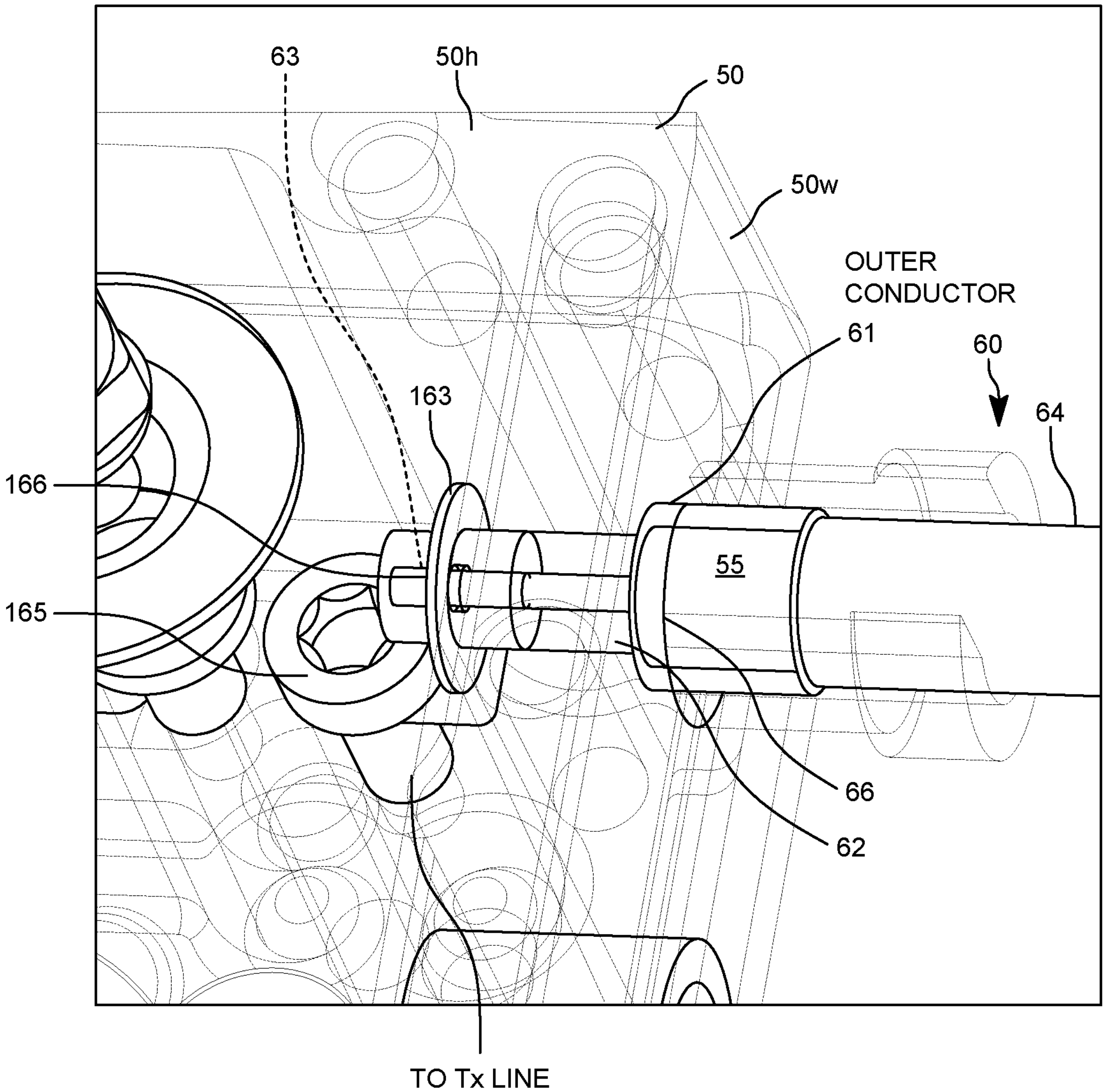
channel to reside forward of the first member. The first member resides in a respective one of the at least one receiving channel against the stop surface. The connector assembly also includes second member with an open channel. The second member is slidably coupled to the first end portion of the at least one cable and presses the first member against the stop surface.

20 Claims, 10 Drawing Sheets

(51) **Int. Cl.**
H01R 9/05 (2006.01)
H01R 13/622 (2006.01)
H01R 103/00 (2006.01)

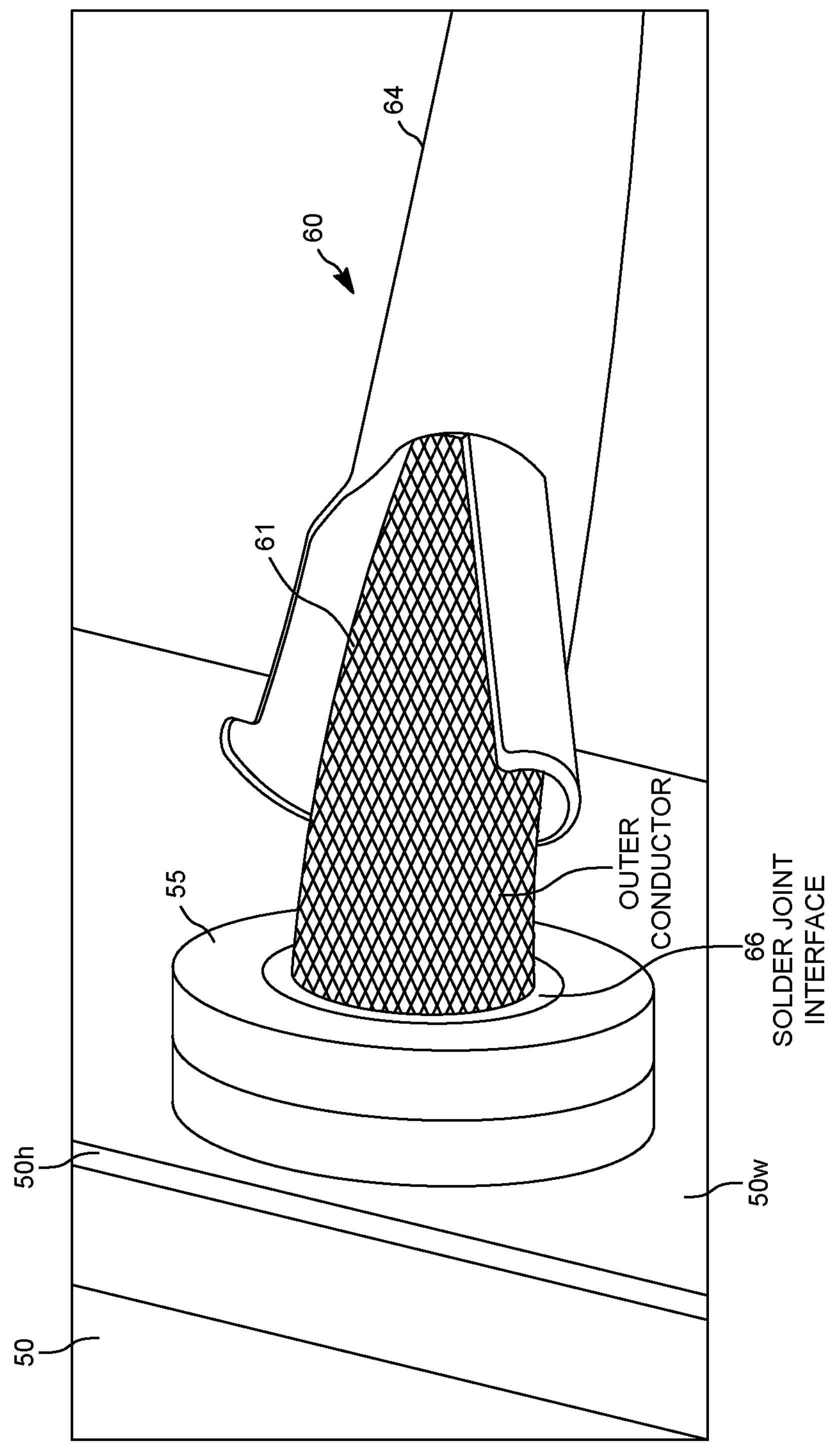


(PRIOR ART)
FIG. 1



(PRIOR ART)

FIG. 2



(PRIOR ART)
FIG. 3

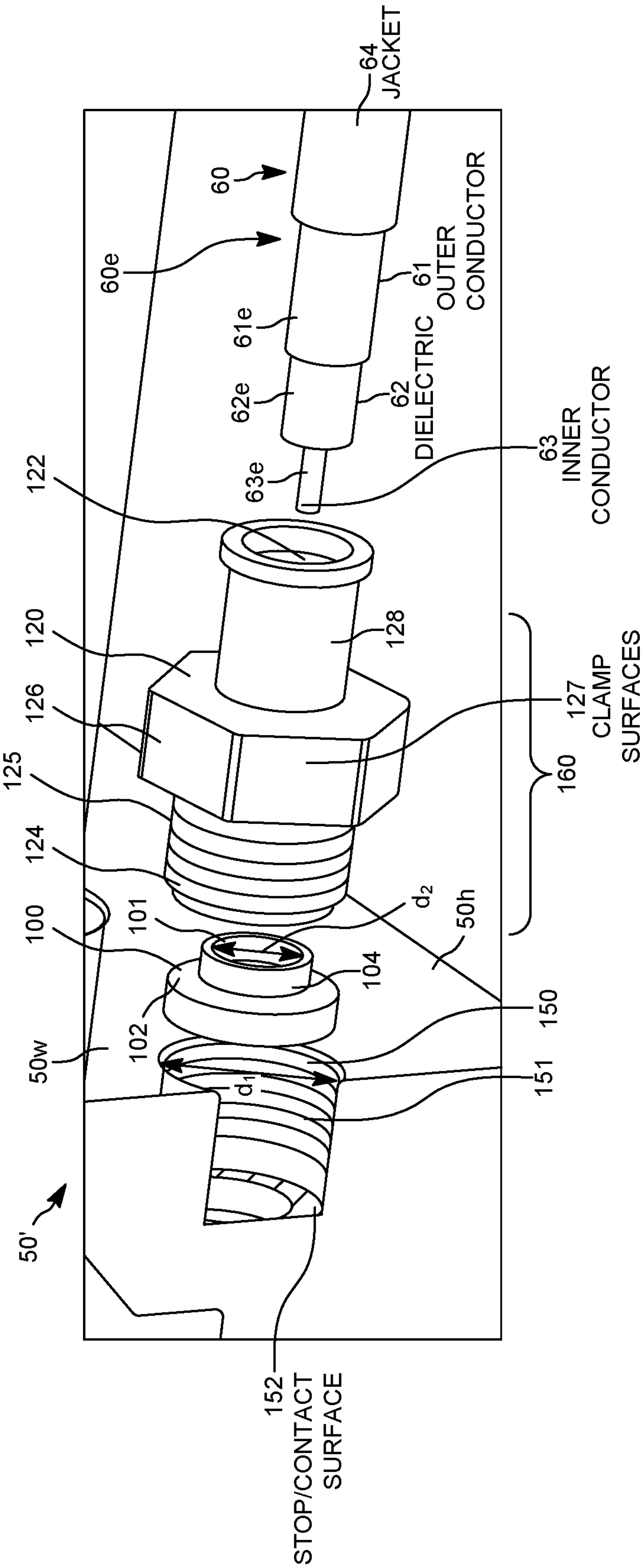

64
JACKET
60
60e
61
OUTER
CONDUCTOR
61e
62e
62
DIELECTRIC
63e
63
INNER
CONDUCTOR
122
120
128
126
127
CLAMP
SURFACES
125
160
124
101
d_2
100
50h
104
102
150
50w
d_1
151
50'
152
STOP/CONTACT
SURFACE

FIG. 4

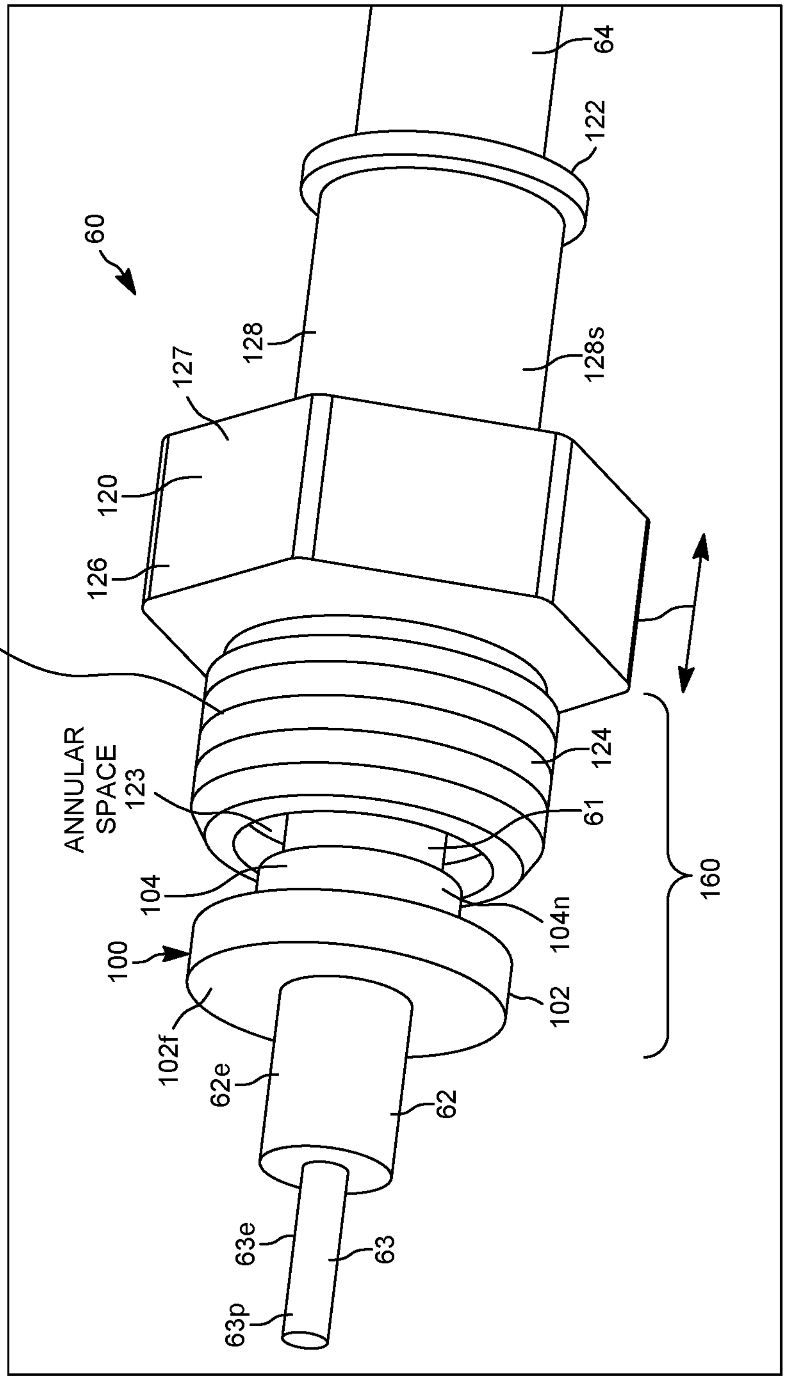

60
64
122
128
128s
127
120
126
125
ANNULAR
SPACE
123
124
61
104
104n
160
100
102
102f
62e
62
63e
63
63p

FIG. 5

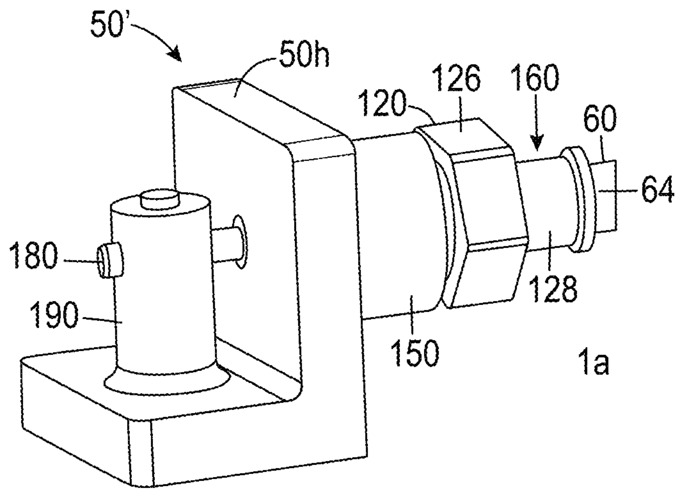

50'
50h
120
126
160
60
64
180
190
128
150
1a

FIG. 6

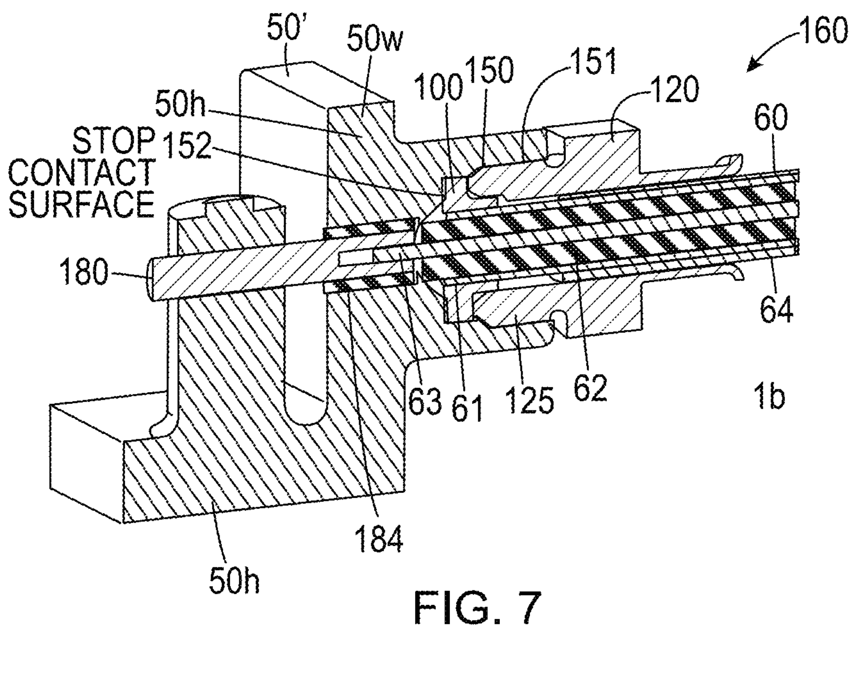

50'
50w
160
50h
100
150
151
120
60
STOP
CONTACT
SURFACE
152
180
64
63
61
125
62
1b
184
50h

FIG. 7

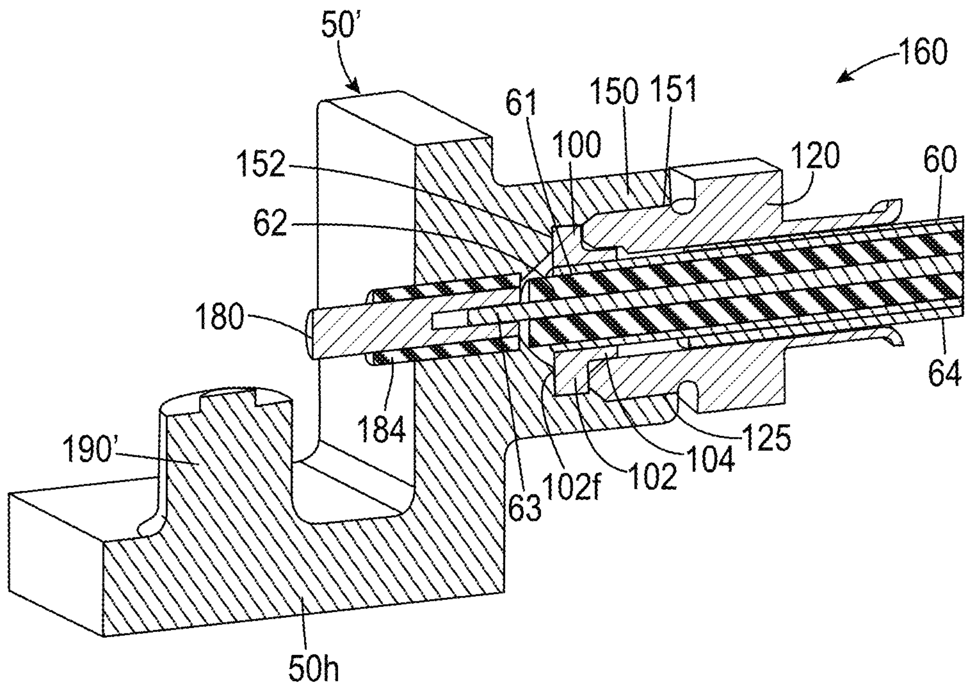

50'
160
61
150
151
100
152
120
60
62
180
64
184
125
190'
104
102
102f
63
50h

FIG. 8

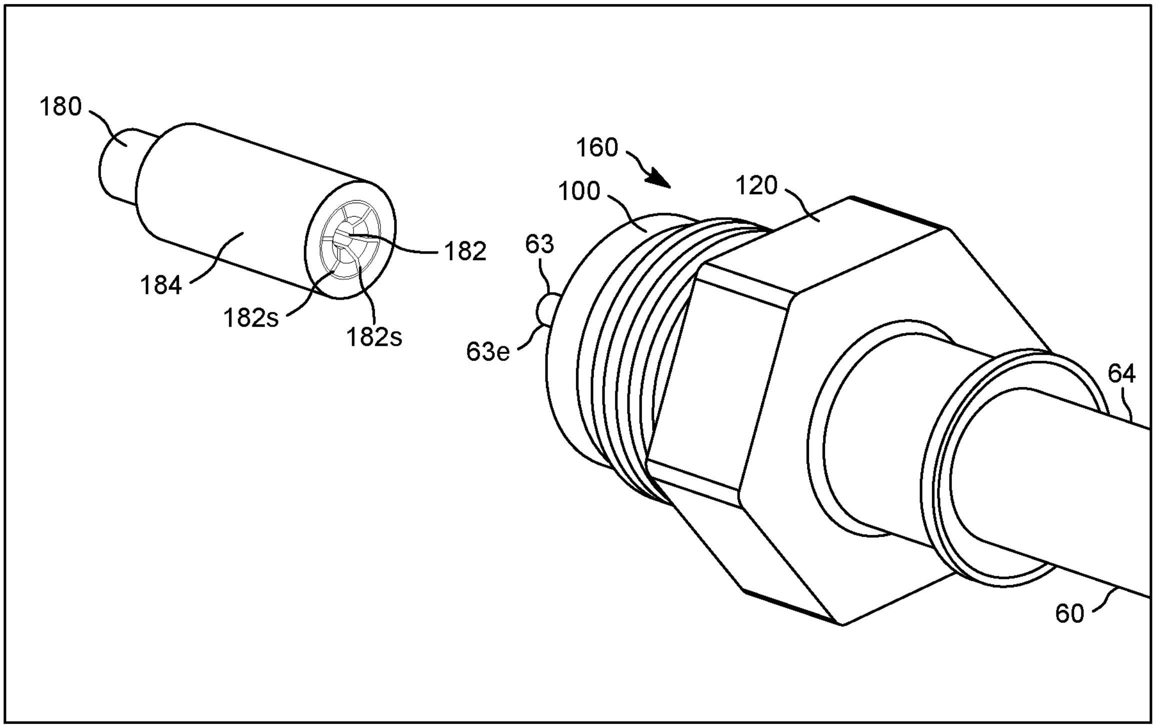

180
160
100
120
182
63
184
182s
182s
63e
64
60

FIG. 9

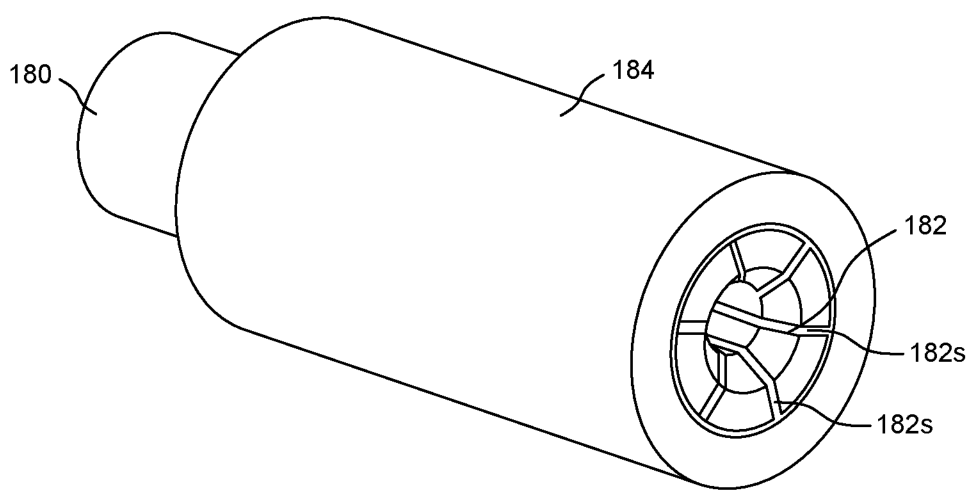

180
184
182
182s
182s

FIG. 10

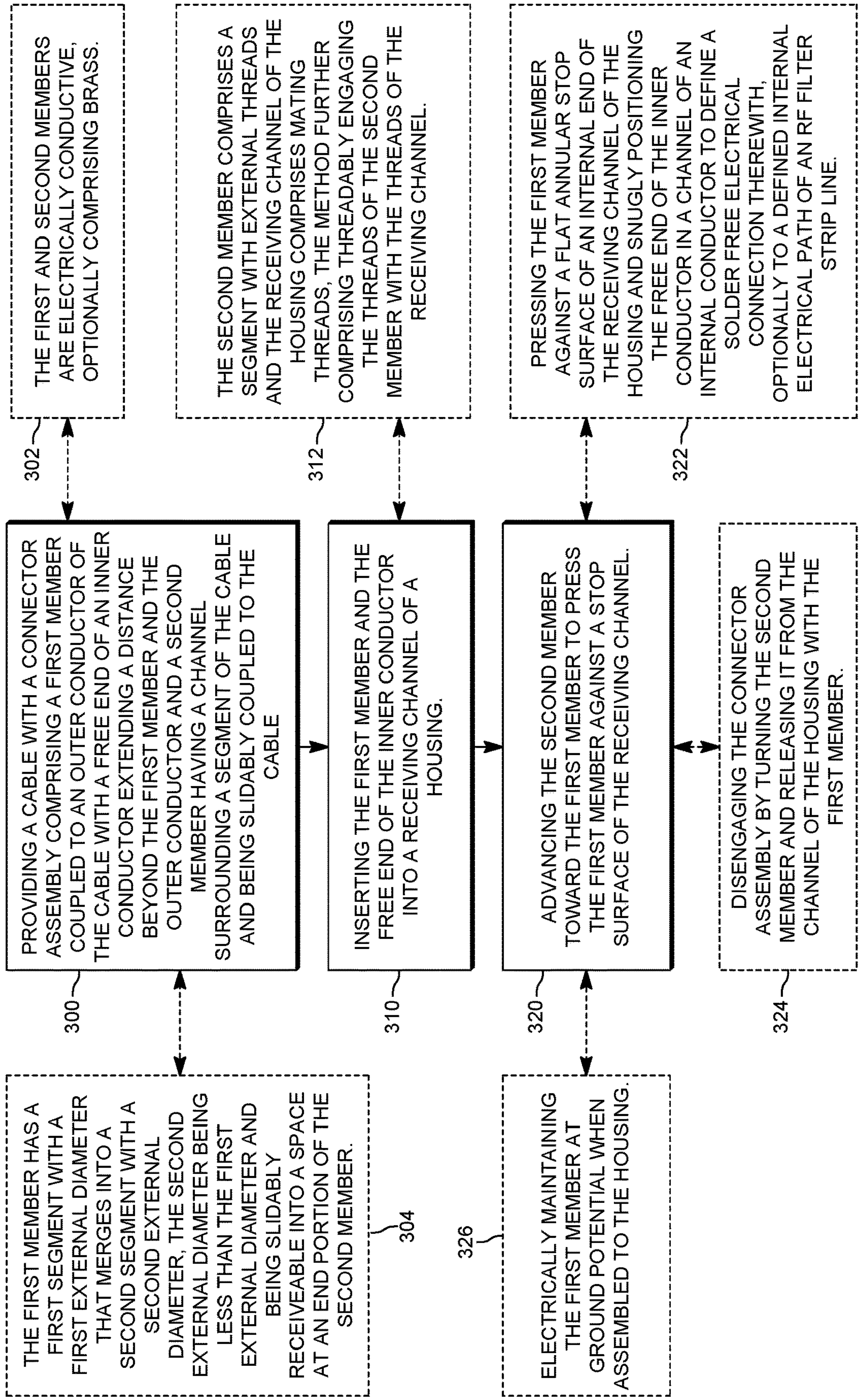

300
PROVIDING A CABLE WITH A CONNECTOR ASSEMBLY COMPRISING A FIRST MEMBER COUPLED TO AN OUTER CONDUCTOR OF THE CABLE WITH A FREE END OF AN INNER CONDUCTOR EXTENDING A DISTANCE BEYOND THE FIRST MEMBER AND THE OUTER CONDUCTOR AND A SECOND MEMBER HAVING A CHANNEL SURROUNDING A SEGMENT OF THE CABLE AND BEING SLIDABLY COUPLED TO THE CABLE
310
INSERTING THE FIRST MEMBER AND THE FREE END OF THE INNER CONDUCTOR INTO A RECEIVING CHANNEL OF A HOUSING.
320
ADVANCING THE SECOND MEMBER TOWARD THE FIRST MEMBER TO PRESS THE FIRST MEMBER AGAINST A STOP SURFACE OF THE RECEIVING CHANNEL.
302
THE FIRST AND SECOND MEMBERS ARE ELECTRICALLY CONDUCTIVE, OPTIONALLY COMPRISING BRASS.
312
THE SECOND MEMBER COMPRISES A SEGMENT WITH EXTERNAL THREADS AND THE RECEIVING CHANNEL OF THE HOUSING COMPRISES MATING THREADS, THE METHOD FURTHER COMPRISING THREADS ENGAGING THE THREADS OF THE SECOND MEMBER WITH THE THREADS OF THE RECEIVING CHANNEL.
322
PRESSING THE FIRST MEMBER AGAINST A FLAT ANNULAR STOP SURFACE OF AN INTERNAL END OF THE RECEIVING CHANNEL OF THE HOUSING AND SNUGLY POSITIONING THE FREE END OF THE INNER CONDUCTOR IN A CHANNEL OF AN INTERNAL CONDUCTOR TO DEFINE A SOLDER FREE ELECTRICAL CONNECTION THEREWITH, OPTIONALLY TO A DEFINED INTERNAL ELECTRICAL PATH OF AN RF FILTER STRIP LINE.
304
THE FIRST MEMBER HAS A FIRST SEGMENT WITH A FIRST EXTERNAL DIAMETER THAT MERGES INTO A SECOND SEGMENT WITH A SECOND EXTERNAL DIAMETER, THE SECOND EXTERNAL DIAMETER BEING LESS THAN THE FIRST EXTERNAL DIAMETER AND BEING SLIDABLY RECEIVEABLE INTO A SPACE AT AN END PORTION OF THE SECOND MEMBER.
326
ELECTRICALLY MAINTAINING THE FIRST MEMBER AT GROUND POTENTIAL WHEN ASSEMBLED TO THE HOUSING.
324
DISENGAGING THE CONNECTOR ASSEMBLY BY TURNING THE SECOND MEMBER AND RELEASING IT FROM THE CHANNEL OF THE HOUSING WITH THE FIRST MEMBER.

FIG. 11

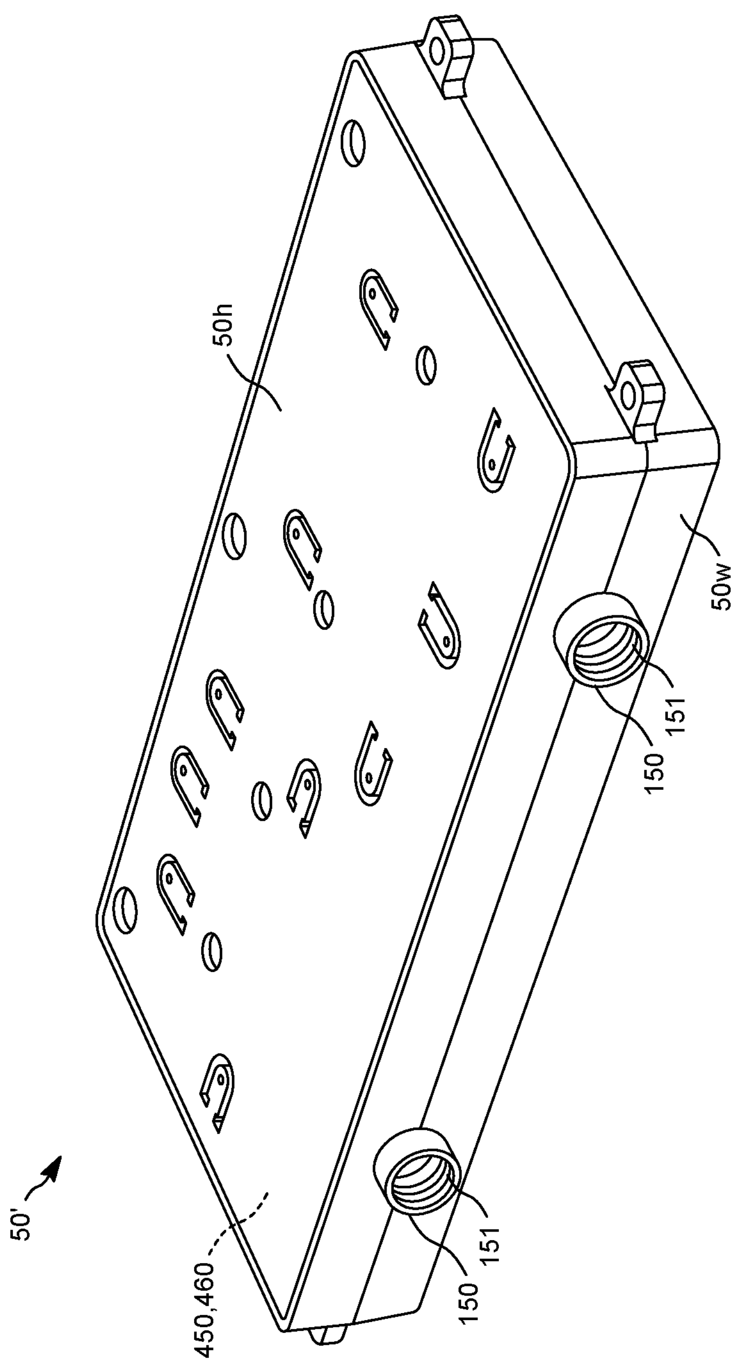


FIG. 12

CABLES WITH CONNECTOR ASSEMBLIES, FILTER UNITS CONFIGURED TO RELEASABLY COUPLE TO THE CONNECTOR ASSEMBLIES AND RELATED METHODS

FIELD OF THE INVENTION

The present invention relates generally to connector assemblies that are particularly suitable for use with filter units for cellular communications systems.

BACKGROUND

Wireless base stations are well known in the art and typically include, among other things, baseband equipment, radios and antennas. The antennas are often mounted to a support structure such as a tower or other elevated structure such as a pole, rooftop, wall, water tower or the like. Typically, multiple antennas are mounted on the support structure, and one or more baseband units and radios can be connected to each antenna. Each antenna provides cellular service to a defined coverage area or “sector.”

FIG. **1** is a highly simplified, schematic diagram that illustrates a conventional cellular base station **10**. As shown in FIG. **1**, the cellular base station **10** includes an antenna tower **30** and an equipment enclosure **20** that is located at the base of the antenna tower **30**. A plurality of baseband units **22** and radios **24** are located within the equipment enclosure **20**. Each baseband unit **22** is connected to a respective one of the radios **24** and is also in communication with a backhaul communications system **44**. Three sectorized antennas **32** (labelled antennas **32-1**, **32-2**, **32-3**) are located at the top of the antenna tower **30**. Three cables **34** (which are bundled together in FIG. **1** to appear as a single cable) connect the radios **24** to the respective antennas **32**. Each cable **34** may be connected to a filter unit **50** (labeled as filter units **50-1**, **50-2**, **50-3**) and both the transmit and receive signals for each radio **24** may be carried on a single (coaxial and/or fiber optic) cable **34**. In many cases, the radios **24** are located at the top of the tower **30** instead of in the equipment enclosure **20** in order to reduce signal transmission losses. The filter units **50** may be located, for example, within or adjacent the antennas **32**.

Cellular base stations typically use directional antennas **32** such as phased array antennas to provide increased antenna gain throughout a defined coverage area. A typical phased array antenna **32** may be implemented as a linear array of radiating elements mounted on a panel, with perhaps 5-20 radiating elements per linear array. Typically, each radiating element is used to (1) transmit radio frequency (“RF”) signals that are received from a transmit port of an associated radio **24** and (2) receive RF signals from mobile users and feed such received signals to the receive port of the associated radio **24**. Filter units such as duplexers are typically used to connect the radio **24** to each respective radiating element of the antenna **32**. A “duplexer” refers a well-known type of multi-port filter assembly that is used to connect both the transmit and receive ports of a radio **24** to an antenna **32** or to a radiating element of multi-element antenna **32**. Duplexers are used to isolate the RF transmission paths to the transmit and receive ports of the radio **24** from each other while allowing both RF transmission paths access to the radiating element of the antenna **32**, and may accomplish this even though the transmit and receive frequency bands may be closely spaced together.

SUMMARY OF THE INVENTION

Embodiments of the present invention provide connector assemblies that releasably couple cables to filter units without requiring a soldered interface to a respective housing of the filter units.

Embodiments of the present invention are directed to cables that comprise connector assemblies that releasably couple to a receiving channel of a housing using a threaded member thereby providing a solderless connection to the housing.

Embodiments or the present invention provide housings having at least one threaded channel that releasably couples to a respective threaded member of a connector assembly.

The filter unit in any of the embodiments of the aspects of the present invention can be a duplexer, a diplexer, a combiner and/or as other filters for cellular communications systems and other applications.

The connector assemblies may be useful for other applications.

Embodiments of the present invention are directed to filter units that include a housing having a receiving channel with a stop surface that is electrically conductive; and a cable having a connector assembly on a first end portion. The first end portion has an end portion of an inner conductor with a free end, an end portion of an outer conductor that terminates a distance rearward of the end portion of the inner conductor, and an end portion of a dielectric residing between the inner conductor and the outer conductor. The connector assembly includes: a first member with an open channel and a second member. The first member is coupled to the end portion of the outer conductor with the free end of the inner conductor and the end portion of the dielectric extending through the open channel to reside forward of the first member. The first member abuts the stop surface. The second member has an open channel that slidably receives the cable. The second member is detachably coupled to the first member and at least partially resides in the receiving channel. When fully assembled to the housing, the second member presses the first member against the stop surface.

The first member can include a first segment with an annular flat end face and a second segment comprising a neck. The second member can define an annular space about the end portion of the outer conductor. The neck of the first member can be sized and configured to reside in the annular space.

The second member can have a first segment with external threads. The at least one receiving channel can have an internal surface with threads that can threadably engage the external threads of the first segment of the second member to thereby define a releasably detachable solderless coupling of the second member to the receiving channel.

The first member and the second member of the connector assembly can be electrically conductive.

The first member and the second member can be formed of brass, optionally the first member can also include silver plating.

The filter unit can also include a center conductor in the housing that is aligned with the receiving channel and that can be electrically and physically connected to the free end of the inner conductor to thereby define a solderless connection therebetween.

The center conductor can have a longitudinally extending body with opposing first and second end portions. The first end portion can have a channel with longitudinally and radially extending slits that are circumferentially spaced apart.

The channel of the center conductor can terminate in the longitudinally extending body before the second end portion.

The filter unit can also include an annular dielectric in the housing, surrounding at least a portion of the center conductor.

The second member can have first, second and third segments surrounding the open channel. The first segment can have external threads that resides over the end portion of the outer conductor. The second segment can have a plurality of circumferentially spaced apart flat clamping surfaces. The third segment can have a cylindrical shoulder residing over at least a part of an outer jacket of the at least one cable.

The stop surface can reside at an inner end portion of the receiving channel. The stop surface can surround an open longitudinally extending channel that extends a distance inwardly thereof to position the free end of the inner conductor inside a center conductor held therein.

Other embodiments are directed to a cable assembly. The cable assembly includes a coaxial cable having an inner conductor, an outer conductor, a dielectric between the inner conductor and the outer conductor and an outer jacket surrounding the outer conductor over a length of the coaxial cable. The coaxial cable has an end portion configured with an end portion of an inner conductor having an exposed free end, an end portion of an outer conductor terminating a distance rearward of the end portion of the inner conductor, and an end portion of a dielectric residing between the inner conductor and the outer conductor terminating a distance rearward of the end portion of the inner conductor. The cable assembly also includes a connector assembly coupled to the end portion of the coaxial cable. The connector assembly can include: a first member with an open channel, the first member coupled to the end portion of the outer conductor with the free end of the inner conductor and the end portion of the dielectric extending through the open channel to reside forward of the first member; and a second member with an open channel that slidably receives the first end portion of the at least one cable and moves axially relative to the first member between installed and uninstalled positions.

The first member can have a first segment with an annular flat end face and a second segment comprising a neck. The second member can define an annular space about the end portion of the outer conductor. The neck of the first member can be sized and configured to reside in the annular space.

The second member can have a first segment with external threads to thereby define a releasably detachable solderless coupling of the second member to a threaded receiving channel in a target device and that forces the first member against a stop surface therein.

The first member and the second member of the connector assembly can be electrically conductive.

The first member and the second member can be formed of brass. Optionally the first member can also have a silver plating.

The second member can have first, second and third segments surrounding the open channel. The first segment can have external threads and reside over the end portion of the outer conductor. The second segment can have a plurality of circumferentially spaced apart flat clamping surfaces. The third segment can have a cylindrical shoulder enclosing a segment of the outer jacket of the cable.

Yet other embodiments are directed to methods of attaching a cable to a target device. The methods include: providing a cable with a connector assembly on an end portion thereof, the connector assembly having a first member coupled to an outer conductor and defining an open channel that surrounds an end portion of a dielectric and an end portion of an inner conductor with a free end of the inner conductor extending forward thereof, and also having a second member slidably coupled to the end portion of the cable. The methods also include: inserting the first member into a receiving channel of a target device; advancing the second member toward the first member in the receiving channel; and forcing the second member to abut the first member and press the first member against a stop surface in the receiving channel to define an electrical ground connection with the target device.

The receiving channel can have an inner surface with threads and the second member can have external threads. The advancing can be carried out to threadably engage the threads of the receiving channel and the threads of the second member to couple the second member to the target device and force the second member to abut the first member.

The target device can be a filter unit of a communications system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a highly simplified, schematic diagram of a conventional cellular base station.

FIG. **2** is an enlarged partial perspective view of a prior art filter unit and coaxial cable with two soldered connection interfaces for one end portion of the cable.

FIG. **3** is a greatly enlarged partial perspective view of a prior art coaxial cable with the outer conductor soldered to the housing.

FIG. **4** is an enlarged exploded view of a cable comprising a connector assembly for coupling to a housing according to embodiments of the present invention.

FIG. **5** is an assembled view of the connector assembly shown in FIG. **4** according to embodiments of the present invention.

FIG. **6** is a side perspective view of the connector assembly shown in FIGS. **4** and **5**, shown coupled to a channel of the housing and an internal connection interface (only a portion of the housing is shown) according to embodiments of the present invention.

FIG. **7** is a section view of the device shown in FIG. **6**.

FIG. **8** is a section view of a similar device to that shown in FIG. **7**, but shown with an alternate internal connection interface according to embodiments of the present invention.

FIG. **9** is an exploded view of a distal end portion of the cable with the connector assembly aligned with an internal connection interface for the inner conductor according to embodiments of the present invention.

FIG. **10** is an enlarged side perspective view of the internal connection interface shown in FIG. **9**.

FIG. **11** is a flow chart of actions that can be used to detachably couple a coaxial cable to a housing according to embodiments of the present invention.

FIG. **12** is a perspective view of an example filter unit according to embodiments of the present invention.

DETAILED DESCRIPTION

The present invention is described more fully hereinafter with reference to the accompanying drawings, in which some embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

Like numbers refer to like elements throughout. In the figures, the thickness of certain lines, layers, components, elements or features may be exaggerated for clarity. The terms "FIG." and "Fig." are used interchangeably with the word "Figure" in the specification and/or figures.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, steps, operations, elements, components, and/or groups thereof. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the specification and relevant art and should not be interpreted in an idealized or overly formal sense unless expressly so defined herein. Well-known functions or constructions may not be described in detail for brevity and/or clarity.

It will be understood that when an element is referred to as being "on", "attached" to, "connected" to, "coupled" with, "contacting", etc., another element, it can be directly on, attached to, connected to, coupled with or contacting the other element or intervening elements may also be present. In contrast, when an element is referred to as being, for example, "directly on", "directly attached" to, "directly connected" to, "directly coupled" with or "directly contacting" another element, there are no intervening elements present. It will also be appreciated by those of skill in the art that references to a structure or feature that is disposed "adjacent" another feature may have portions that overlap or underlie the adjacent feature.

Spatially relative terms, such as "under", "below", "lower", "over", "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures.

It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is inverted, elements described as "under" or "beneath" other elements or features would then be oriented "over" the other elements or features. Thus, the exemplary term "under" can encompass both an orientation of "over" and "under". The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly. Similarly, the terms "upwardly", "downwardly", "vertical", "horizontal" and the like are used herein for the purpose of explanation only unless specifically indicated otherwise.

The term "about" means that the noted parameter can vary somewhat from the stated number, typically by +/−20%.

FIG. **2** illustrates a prior art coaxial cable **60** with an outer conductor **61** soldered at a solder interface **66** to an outer wall **50***w* of a housing **50***h* of a filter unit **50**. The solder interface **66** is typically provided by heating solder paste positioned in a cylindrical coupler **55** attached to the housing **50***h* that extends out of the outer wall **50***w* of the housing. FIG. **3** is an enlarged partial view of the soldered interface **66** of the outer conductor **61** and outer wall **50***w*. FIG. **2** also shows that the inner (center) conductor **63** is soldered at a solder interface **166** inside the housing **50***h* to a washer **163** that is coupled to a conductive (e.g., copper) screw **165** to connect to a transmission line. Once the soldered interface joints **66**, **166** are made and intact, it is difficult to remove the cable **60** from the housing **50***h*. Heat must be applied to the soldered interface joints **66**, **166** (indicated by arrows in FIG. **2**), typically concurrently and at least the soldered interface **66** of the outer conductor **61** may require an undesirable level of heat to melt the solder to be able to release the cable **60** from the housing **50***h*.

Referring to FIGS. **4** and **5**, embodiments of the present invention provide a cable **60** with an end portion **60***e* and comprising a connector assembly **160** that attaches to the cable **60** and that is configured to provide a releasably engageable, solderless connection to a housing **50***h*, such as a housing of a filter assembly.

The term "filter assembly" and "filter assemblies" are used interchangeably with the terms "filter unit" and "filter units", respectively, herein. The filter assemblies can be duplexers, diplexers, combiners and/or as other filters for cellular communications systems and other applications.

As shown, the cable **60** is a coaxial cable with an outer conductor **61**, a dielectric **62** and an inner conductor **63**. The inner conductor **63** can be sufficiently rigid to define a self-supporting shape with a free exposed end portion **63***e* that extends a distance beyond the dielectric **62** and the outer conductor **61**. The inner conductor **63** and the dielectric **62** can have respective end portions **63***e*, **62***e* that extend a distance beyond an end portion **61***e* of the outer conductor **61** and the inner conductor **63** can extend a distance beyond the dielectric **62**. The cable **60** can have an external jacket **64** that can terminate a distance rearward of the end portion **61***e* of the outer conductor **61**. The outer conductor **61** can have a braided configuration (FIG. **3**).

It is contemplated that the connector assemblies **160**, while particularly suitable for filter units, may also be suitable for other end use applications and/or other types of cables **60**.

As shown, the connector assembly **160** comprises a first member **100** that releasably couples to a second member **120**. The first member **100** can have an open and longitudinally extending through channel **101** that is aligned with, typically concentric with, the through channel **122** of the second member **120** and that is sized and configured to couple to the outer conductor **61** of the cable **60**. That is, the first member **100** is sized and configured to attach to the outer conductor **61** of the cable **60** with end portions **62***e*, **63***e* of the dielectric **62** and inner conductor **63**, respectively, extending through the channel **101** to reside a distance forward of the first member **100** (FIG. **5**).

The first member **100** can be soldered to the outer conductor **61**. A solder paste can be used to solder the first member **100** to the outer conductor **61** about an entire circumference thereof.

The longitudinally extending open through channel **122** of the second member **120** can be elongate and longer than the open through channel **101** of the first member **100**. The second member **120** is not required to fixedly attach to the cable **60** and can be configured to "float" axially about the outer conductor **61** and/or jacket **64** relative to the first member **100** when not attached to (prior to assembly with) the housing **50***h* as shown by the axially extending arrows in FIG. **5**.

As shown, the first member **100** can have a first segment **102** with a first outer diameter d1 that merges into a second segment **104** with a second outer diameter d2, with d2<d1, typically d2 is at least 20% less than d1. The second segment **104** can define a longitudinally or axially extending neck **104***n* that is slidably receivable into an annular space **123** between the outer conductor **61** and an end portion of the second member **120** and that faces the first member **100**.

The first segment **102** of the first member **100** can have a flat annular end face **102***f* that can electrically and physically engage a stop surface **152** (FIGS. **4** and **7**) of a channel **150** in the housing **50***h* of a target device, optionally a filter unit **50'**. The stop surface **152** can be electrically conductive. The first member **100** can thus provide an electrical ground connection when assembled in the receiving channel **150** of the housing **50***h*.

The first member **100** and the second member **120** can comprise an electrically conductive material. For example, brass or a substrate with a conductive coating such as silver plated components or combinations thereof. In some particular embodiments, the first member **100** can be silver plated or coated brass while the second member **120** can comprise brass without requiring a silver plating or coating.

The second member **120** can comprise a first segment **124** on a first end portion with external threads **125**. The second member **120** can comprise a second segment **126** that has a greater outer diameter than the first segment **124**. The second member **120** can comprise a third segment **128** on an opposing end portion that extends a distance away from the second segment **126**. The third segment **128** can be longer than the second segment **126** (the length dimension being in a longitudinally or axially extending direction). The third segment **128** can have an outer diameter over at least a major portion of its length that is less than maximal outer diameters of the first and second segments **124**, **126**, respectively.

The third segment **128** can define a shoulder **128***s* that has an inner diameter that is about the same or within about +10% or less of a diameter of the cable (with the jacket **64**) to provide bending resistance/support structure to the cable **60** and can surround a segment of the jacket **64** of the cable **60**.

The receiving channel **150** can have threads **151** on an inner surface thereof that threadably engage the threads **125** of the second member **120**. However, it is contemplated that other embodiments can use a frictional attachment of the second member **120** to the housing **50***h* without requiring threads **151** or **125**.

The second segment **126** can reside intermediate of the first and third segments and can comprise external clamping surfaces **127**. The clamping surfaces **127** can comprise a plurality of circumferentially spaced apart external flat surfaces for allowing users to clamp against these surfaces to turn the second member **120** to threadably advance into a receiving channel **150** having threads **151** that matably engage the threads **125** of the second member **120**.

The second member **120** can slidably receive a subsegment of the cable **60** through the open channel **122**. The second member **120** can be configured to position the jacket **64** in the third segment **128** of the second member **120** and position the end portion **61***e* of the outer conductor **61** outside the first segment **124** of the second member, adjacent to and facing the first member **100** (FIG. **5**).

Referring to FIGS. **4**, **7** and **8**, at least a portion of the second member **120** can couple to a receiving channel **150** of a housing **50***h*. The second member **120** can be configured to have different positons with respect to the first member **100**. A first position is shown in FIG. **5** where the second member **120** can float axially relative to the first member **100**. A second position in a fully assembled configuration is shown in FIGS. **7** and **8** whereby the second member **120** is closer to the first member **100** and the second segment **104** of the first member **100** is slidably received into a facing end portion of the second member **120**. Thus, the second member **120** can travel toward the first member **100** when coupled to the receiving channel **150** of the housing **50** as the second member **120** is advanced into the receiving channel **150**.

The (free) end portion **63***e* of the inner conductor **63** can define a connection pin **63***p* that extends into a channel **182** of a center conductor **180** (FIG. **7**) in a housing **50***h* aligned with an axially extending centerline of the receiving channel **150**. The free end **63***e* or pin **63***p* can have a length that is in a range of about 1 mm to about 70 mm.

Referring to FIGS. **6**-**8**, the receiving channel **150** can have a stop surface **152** that is flat to abut the flat end face **102***f* of the first member **100**. The stop surface **152** can be a flat annular stop surface. The first member **100** is pressed forward against the stop surface **152** by the second member **120** when the second member **120** is (threadably) coupled to (the threads **151** of) the receiving channel **150**. Thus, when assembled, the first member **100** and the second member **120** can be physically coupled to the receiving channel **150**.

The receiving channel **150** can be formed into an outer wall **50***w* of the housing **50***h* or be provided by a cylindrical coupler that is attached to the outer wall **50***w*. The receiving channel **150** can project outward from the outer wall **50***w* or be flush or even extend inward of the outer wall (not shown).

Referring to FIGS. **6**-**8**, the free end **63***e* of the inner conductor **63** can engage a center conductor **180**. The center conductor **180** can be axially aligned with the receiving channel **150**. The center conductor **180** can comprise an annular dielectric spacer **184** that surrounds the center conductor **180**. The center conductor **180** is electrically conductive and can comprise gold or other suitable conductive material. The free end **63***e* of the inner conductor **63** can slidably extend into a longitudinally extending channel **182** of the center conductor **180**. The channel **182** can terminate a short distance in front of the tip of the free end of the inner conductor **63**.

The free end **63***e* of the inner conductor **63** can frictionally engage the center conductor **180** to define a solder free electrical connection therewith. In other embodiments, the free end **63***e* may be soldered to the center conductor **180** (not shown).

The center conductor **180** can be soldered to a strip line (not shown). FIGS. **6** and **7** illustrate the center conductor **180** held by a boss **190** and the center conductor **180** can electrically couple to a strip line of an RF filter, such as a transmission line.

FIG. **8** illustrates am embodiment where no boss is provided and a separate (RF filter) strip line can be used where the center conductor **180** can be soldered.

Where soldered connections are used, a bismuth-tin-silver solder paste, tin-silver-copper solder paste or alternate preform solder material can be used.

Referring to FIGS. **9** and **10**, the connector assembly **160** can be aligned with the center conductor **180** which can be held in the annular dielectric spacer **184**. The center conductor **180** can define a longitudinally extending internal channel **182** with a plurality of radially and longitudinally extending, circumferentially spaced apart slits **182***s*. The slits **182***s* can be sized and configured to snugly receive the free end **63***e* of the inner conductor **63** and provide abutting contact between the inner conductor **63** and the center conductor **180**. The inner conductor **63** can frictionally engage the center conductor **180**.

The connector assemblies **160** can allow cables **60** to be replaced, such as when damaged, by simply unscrewing the second member **120** from the receiving channel **150** and pulling the cable **60** with the first member **100** out of the receiving channel **150**.

The connector assemblies **160** can reduce the number of soldering events needed to attach or detach a cable that may reduce damage caused to cables and/or other components by those successive heating events.

Embodiments of the invention can allow filter units **50'** to be tested using standardized test cables without requiring unit specific cables/attachments. Filter units **50'** passing these tests can then be assembled to other corresponding cables **60** with the connector assemblies **160** at an OEM facility or at a field site.

The cables **60** can be manufactured and shipped with the connector assemblies **160** pre-attached for installation at a field site. The cables **60** can be assembled with respective first members **100**, typically soldered together, and slidably mounted second members **120** produced in production batches to have respective connector assemblies **160** attached at a production facility as soldering to specific filter units is not required.

Turning now to FIG. **11**, a flow chart of example actions that can be used to attach a cable to a target housing is illustrated (broken lines indicate optional steps). A cable with a connector assembly is provided. The connector assembly comprises a first member coupled to an outer conductor of the cable with a free end of an inner conductor extending a distance beyond the first member and the outer conductor and a second member having a channel surrounding a segment of the cable, and being slidably coupled to the cable (block **300**). The first member and the free end of the inner conductor are inserted into a receiving channel of a housing (block **310**). The second member is advanced toward the first member to press the first member against a stop surface of the receiving channel (block **320**).

The first and second members are electrically conductive, optionally comprising brass (block **302**).

The second member can comprise a segment with external threads and the receiving channel of the housing comprises mating threads, the method can further comprise threadably engaging the threads of the second member with the threads of the receiving channel (block **312**).

The first member can be pressed against a flat annular stop surface of an internal end of the receiving channel of the housing in response to the advancing step and this can snugly position the free end of the inner conductor in an open channel of a center conductor to define a solder free electrical connection therewith, optionally to a defined internal electrical path of an RF filter strip line (block **322**).

The connector assembly can be disengaged from the receiving channel by turning the second member and releasing it from the receiving channel of the housing with the first member (block **324**).

The first member can have a first segment with a first external diameter that merges into a second segment with a second external diameter, the second external diameter being less than the first external diameter and being slidably receivable into an interior space at an end portion of the second member (block **304**).

The first member can be electrically maintained at ground potential when assembled to the housing (block **326**).

Turning now to FIG. **12**, an example filter unit **50'** is shown. The filter unit **50'** can comprise a plurality of resonator plates that are mounted within a housing to realize a resonant cavity RF filter. As shown, the filter unit **50'** includes a housing **50***h*. First and second resonator plates **450**, **460** can be mounted within the housing **50***h*. The resonator plates may be mounted in a stacked relationship. The resonator plates may be fixed to the housing by continuous solder joints and/or may be die cast integrally with other elements of the housing to provide very high levels of RF and PIM distortion performance. In some embodiments, the filter assemblies **50'** may comprise three port devices such as RF duplexers or diplexers and one or more can comprise a receiving channel **150** that can comprise threads **151** that can releasably engage a connector assembly **160**. In other embodiments, the filter units **50'** may include additional ports to implement multiplexers, triplexers, combiners or the like. See, U.S. Pat. No. 10,050,323 for additional discussions of example filter assemblies, the contents of which are hereby incorporated by reference as if recited in full herein. Other filter unit configurations may be used.

Example filter units **50'** according to embodiments of the present invention may include, for example, two or more ports that are used to electrically connect the filter unit **50'** to other external devices. These ports may include "individual" ports, which refer to ports that are only intended to carry signals having frequencies in specific ranges, and "common" ports, which are intended to carry signals having frequencies in multiple of the specific ranges. For example, when a filter unit/filter assembly according to embodiments of the present invention is a duplexer, the filter assembly will include a first individual port that connects to a transmit path, a second individual port that connects to a receive path, and a common port that connects to a radiating element such as a radiating element of a phased array antenna. In some embodiments, the individual and common ports may be, for example, implemented as coaxial connector ports that are designed to mate with a connector assembly **160** of a coaxial cable **60**. In such embodiments, the inner conductors **63** of each cable maybe connected via the center conductor **180** to one of the resonator plates and the outer conductor **61** of each cable may be connected to the housing **50***h*.

The resonator plates **450**, **460** may each comprise, for example, substantially planar metal plates. The resonator plates **450**, **460** may only be "substantially" planar as they may include, for example, non-planar features such as tuning stubs that may be bent upwardly or downwardly to tune the response of the filter assembly **50'**. Each resonator plate **450**, **460** may be formed of, for example, copper or a copper alloy, although other metals may be used

Embodiments of the invention couple the cables **60** with the connector assemblies **160** using a respective receiving channel **150** to provide highly consistent metal-to-metal connections. As is known in the art, Passive Intermodulation ("PIM") distortion may occur when two or more RF signals encounter non-linear electrical junctions or materials along an RF transmission path. Such non-linearities may act like a mixer causing new RF signals to be generated at mathematical combinations of the original RF signals. If the newly generated RF signals fall within the bandwidth of existing RF signals, the noise level experienced by those existing RF signals is effectively increased. When the noise level is increased, it may be necessary reduce the data rate and/or the quality of service. PIM distortion can be an important interconnection quality characteristic for an RF communications system, as PIM distortion generated by a single low quality interconnection may degrade the electrical performance of the entire RF communications system. Thus, ensuring that components used in RF communications systems will generate acceptably low levels of PIM distortion may be desirable.

It should also be noted that in addition to PIM distortion, inconsistent metal-to-metal connections may give rise to reflections in an RF communications system, which increase the return loss along the RF transmission path. Devices that have such inconsistent metal-to-metal connections may therefore exhibit increased insertion loss values. By using the solderless, press-fit connection of the first member **100** against a metal contact stop surface **152**, the filter units **50'** according to embodiments of the present invention may exhibit satisfactory insertion loss performance without requiring soldering.

It will be appreciated that cables **60** with connector assemblies **160** according to embodiments of the present invention may be used to implement a wide variety of different devices including duplexers, diplexers, multiplexers, combiners and the like. It will also be appreciated that the cables **60** with the connector assemblies **160** according to embodiments of the present invention may also be used in applications other than cellular communications systems.

The present invention has been described above with reference to the accompanying drawings, in which certain embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

In the drawings and specification, there have been disclosed typical embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims.

That which is claimed is:

1. A filter unit comprising:

a housing comprising a receiving channel with a stop surface that is electrically conductive; and

a cable comprising a connector assembly on a first end portion, the first end portion comprising an end portion of an inner conductor having a free end, an end portion of an outer conductor terminating a distance rearward of the end portion of the inner conductor, and an end portion of a dielectric residing between the inner conductor and the outer conductor,

the connector assembly comprising:

a first member comprising an open channel, the first member coupled to the end portion of the outer conductor with the free end of the inner conductor and the end portion of the dielectric extending through the open channel to reside forward of the first member, wherein the outer conductor is spaced apart from the stop surface, and wherein the first member abuts the stop surface; and

a second member that is rearward of the first member and comprises an open channel that slidably receives the cable, wherein the second member is detachably coupled to the first member and the first member at least partially resides in the receiving channel of the housing while also coupled to the second member, and wherein, when fully assembled to the housing, the second member presses the first member against the stop surface.

2. The filter unit of claim **1**, wherein the first member is devoid of internal and external threads and comprises a first segment with an annular flat end face that merges into a second segment comprising a neck which defines a rearward end of the first member, wherein the second member defines an annular space about the end portion of the outer conductor, and wherein the neck of the first member is sized and configured to reside in the annular space.

3. The filter unit of claim **1**, wherein the first member is devoid of external threads and has a disk shaped forward segment that merges rearwardly into a smaller diameter neck that defines a rearward end of the first member, wherein the second member comprises a first segment with external threads, wherein the at least one receiving channel comprises an internal surface with threads that threadably engage the external threads of the first segment of the second member to thereby define a releasably detachable solderless coupling of the second member to the receiving channel, and wherein the disk shaped forward segment of the first member is forward of the second member and rearward of the outer conductor and jacket of the first end portion of the coaxial cable.

4. The filter unit of claim **1**, wherein the first member and the second member of the connector assembly are electrically conductive, and wherein the first end portion of the coaxial cable defines first, second, third and fourth axially spaced apart stepped segments at the first end portion of the cable with decreasing respective different outer diameters, with the first segment defined by an outer jacket extending about the outer conductor, the dielectric and the inner conductor, with the second segment defined by the outer conductor surrounding the dielectric and inner conductor and extending forward of the first segment to the end portion of the outer conductor, with the third segment defined by the dielectric surrounding the inner conductor and extending forward of the second segment to the end portion of the dielectric, and with the fourth segment defined by the inner conductor extending forward of the third segment to the free end of the inner conductor.

5. The filter unit of claim **4**, wherein the first member and the second member comprise brass.

6. The filter unit of claim **1**, further comprising a center conductor in the housing that is elongate and aligned with the receiving channel and that is electrically and physically connected to the free end of the inner conductor to thereby define a solderless connection therebetween.

7. The filter unit of claim **6**, wherein the center conductor has a longitudinally extending body with opposing first and second end portions, the first end portion comprising a channel with longitudinally and radially extending slits that are circumferentially spaced apart.

8. The filter unit of claim **7**, wherein the channel of the center conductor terminates in the longitudinally extending body before the second end portion.

9. The filter unit of claim **6**, further comprising an annular dielectric in the housing, surrounding at least a portion of the center conductor and the free end of the inner conductor.

10. The filter unit of claim **1**, wherein the second member comprises first, second and third segments that are axially spaced apart and that surround the open channel of the second member, the first segment comprising external threads and being forward of the second and third segments, the second segment comprising a plurality of circumferentially spaced apart flat clamping surfaces, and the third segment comprising a cylindrical shoulder residing over the first segment of the first end portion of the cable to surround the outer jacket.

11. The filter unit of claim **1**, wherein the stop surface is at an inner end portion of the receiving channel, wherein the stop surface abuts only a forward end of the first member with the outer conductor positioned behind the stop surface and the stop surface surrounds an open longitudinally extending channel that extends a distance inwardly thereof to position the free end of the inner conductor inside a center conductor held therein.

12. A cable assembly, comprising:

a coaxial cable comprising an inner conductor, an outer conductor, a dielectric between the inner conductor and the outer conductor and an outer jacket surrounding the outer conductor over a length of the coaxial cable, wherein the coaxial cable comprises a first end portion configured with an end portion of an inner conductor having an exposed free end, an end portion of an outer conductor terminating a distance rearward of the end portion of the inner conductor, and an end portion of a dielectric residing axially between the end portion of the inner conductor and the end portion of the outer conductor and terminating a distance rearward of the end portion of the inner conductor; and

a connector assembly coupled to the first end portion of the coaxial cable, the connector assembly comprising:

a first member comprising an open channel, the first member coupled to the end portion of the outer conductor with the free end of the inner conductor and the end portion of the dielectric extending through the open channel to reside forward of the first member and with an end of the end portion of the outer conductor terminating at or rearward of a forward end of the first member; and

a second member residing rearward of the first member and comprising an open channel that slidably receives a rearwardly positioned portion of the first member and the first end portion of the coaxial cable and moves axially relative to the first member between installed and uninstalled positions.

13. The cable assembly of claim **12**, wherein the first member is devoid of internal and external threads, wherein the first member comprises a first segment with an annular flat end face and merges into a second segment comprising a neck defining a rearward end of the first member, wherein the second member defines an annular space that extends about the end portion of the outer conductor, and wherein the neck of the first member is sized and configured to reside in the annular space.

14. The cable assembly of claim **12**, wherein the first member is devoid of external threads and has a disk shaped forward segment that merges rearwardly into a smaller diameter neck that defines a rearward end of the first member that slidably engages a conductive stop surface in a target device, and wherein the second member comprises a first segment at a forward end thereof with external threads to thereby define a releasably detachable solderless coupling of the second member to a threaded receiving channel in a target device and that forces the first member against a stop surface therein.

15. The cable assembly of claim **12**, wherein the first member and the second member of the connector assembly are electrically conductive.

16. The cable assembly of claim **15**, wherein the first member and the second member comprise brass.

17. The cable assembly of claim **12**, wherein the second member comprises first, second and third segments surrounding the open channel of the second member, the first segment residing forward of the second and third segments and comprising external threads and residing about the end portion of the outer conductor, the second segment comprising a plurality of circumferentially spaced apart flat clamping surfaces, and the third segment comprising a cylindrical shoulder enclosing a segment of the outer jacket of the cable.

18. A method of attaching a cable to a target device, comprising:

providing a cable with a connector assembly on an end portion thereof, the connector assembly comprising a first member that is electrically conductive and coupled to an outer conductor and defining an open channel that surrounds an end portion of a dielectric and an end portion of an inner conductor with a free end of the inner conductor extending forward thereof whereby the first end portion of the cable defines first, second, third and fourth axially spaced apart stepped segments at the first end portion of the cable with decreasing respective different outer diameters, with the first segment defined by an outer jacket extending about the outer conductor, the dielectric and the inner conductor, with the second segment defined by the outer conductor surrounding the dielectric and inner conductor and extending forward of the first segment to the end portion of the outer conductor, with the third segment defined by the dielectric surrounding the inner conductor and extending forward of the second segment to the end portion of the dielectric, and with the fourth segment defined by the inner conductor extending forward of the third segment to the free end of the inner conductor, and also comprising a second member that is electrically conductive, positioned behind the first member, slidably coupled to the end portion of the cable;

inserting the first member into a receiving channel of a target device;

advancing the second member toward the first member in the receiving channel; and

forcing the second member to abut the first member and press the first member against a stop surface in the receiving channel while the outer conductor is spaced apart from the stop surface to define an electrical ground connection with the target device.

19. The method of claim **18**, wherein the receiving channel has an inner surface with threads, wherein the second member has external threads, and wherein the advancing is carried out to threadably engage the threads of the receiving channel and the threads of the second member to couple the second member to the target device and force the second member to abut the first member.

20. The method of claim **18**, wherein the target device is a filter unit of a communications system.

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